Climate Prediction Program for the Americas (CPPA)
FY 2003 Progress and FY 2004 Plans

Introduction

The Climate Prediction Program for the Americas merges NOAA's CLIVAR Pan American Climate Studies and GEWEX Americas Prediction Project into a single integrated competitive research program to improve operational intraseasonal to interannual climate and hydrologic forecasting. To achieve its goal, CPPA supports research to:

- Improve the understanding and model simulation of ocean, atmosphere and land-surface processes through observations, data analysis, and modeling studies;
- Determine the predictability of climate variations on intra-seasonal to interannual time scale, including predictability of the continental-scale monsoon systems across the Americas;
- Advance NOAA's operational climate forecasts, monitoring, and analysis systems; and
- Develop climate-based hydrologic forecasting capabilities and decision support tools for water resource applications.

CPPA research also directly advances climate change science by:

- Quantifying and reducing uncertainties in climate system feedbacks from clouds, water vapor, atmospheric convection, ocean circulation and vegetation, which are responsible for large uncertainties in climate change projections (just as they are in shorter-term climate forecasts);
- Improving global model credibility in simulating the natural patterns of climate variability through which global climate change may be expressed;
- Testing techniques for downscaling from global to regional scales; and
- Developing strategies for interpreting SI climate predictions for water resource applications that can also be applied in interpreting future projected climate scenarios for longer-term resource management.

The scientific basis for CPPA lies in the climate system's predictability determined by variations of the ocean and land surface conditions. The program draws together the coupled climate modeling expertise of PACS, with its emphasis on the processes that couple climate variability over the oceans to that over the land, and the regional and hydrological modeling expertise of GAPP, which emphasizes the processes that couple the land surface to the overlying atmosphere. Motivation for a unified program arises from a common goal to improve climate forecasts based on surface boundary forcing.

The transfer of research results directly to operations is of primary importance. PACS brings to CPPA the concept of climate process and modeling teams designed to accelerate improvement of climate models by more closely linking climate process research to model development and testing activities. Research teams, comprised of observationalists, process modelers, operational model developers, and model diagnosticians work collectively to transfer theoretical and process model understanding into improved treatment of processes in climate models used for operational prediction. GAPP brings to CPPA a valuable technology transfer mechanism, the Core Project, which provides block funding annually to NCEP and the Office of Hydrology to provide an operational pathway for the infusion of research understanding into operational climate prediction systems and NWS operational hydrologic forecasts. The Core Project achieves this objective through internal development and operational activities, and through active collaboration with the broader science community. Linking these complimentary approaches will provide CPPA an effective means to more quickly deliver forecast system improvements.

The merger of PACS and GAPP was initially conceptualized during 2003 as NOAA was developing a more highly integrated Intra-Seasonal to Interannual Prediction (ISIP) Program. Careful planning of a unified CPPA is underway during the 2004 transition year. The following presentation of progress and plans for CPPA reflects the somewhat distinct foci and approaches of the PACS and GAPP programs, while signaling the eventual program structure to emerge by 2005.

Progress and Plans

1. Understanding and simulating ocean-atmosphere processes

1a. Eastern Pacific Investigations of Climate (EPIC)

Anomalous sea surface temperatures in the eastern tropical Pacific perturb the atmosphere and alter climate over Pan America. ENSO model intercomparison studies reveal serious deficiencies in simulations of the seasonal circulation, cloudiness and sea surface temperature in eastern Pacific. Processes that determine the annual march of sea surface temperature are only partly known, yet crucial to the annual march of the ITCZ and the northwestward shift of the American monsoon from South to North America. Further, coupled models exhibit considerable sensitivity to changes in parameterization of the extensive stratus deck over the southeast Pacific. Pilot observations of surface heat fluxes in the eastern Pacific reveal that modeled fluxes vary by 20-40 Wm^{-2}, outside the accuracy limit of 10 Wm^{-2} for climate prediction.

A comprehensive multi-agency, multinational process study, Eastern Pacific Investigations of Climate (EPIC), was launched in 1999 to markedly improve the understanding of the coupled ocean-atmosphere system in the eastern tropical Pacific and advance seasonal-to-interannual predictions of this region and the remote regions influenced by its variability. An intensive field campaign in partnership with Ecaudor, Chile, and Mexico during the boreal fall of 2001 captured high resolution observations to illuminate the structure and advance the model characterization of key ocean, atmosphere and coupled processes in the eastern Pacific.

In FY03, PACS supported 16 observational, analysis, and modelling projects studying eastern Pacific variability and predictability. Following are highlights of research activities and findings.

- Enhanced monitoring: Building upon the ENSO observing system, PACS has made a major investment to sustain enhanced observations of the eastern Pacific ocean and atmosphere over the past four years. The easternmost TAO buoy line has been enhanced with additional moorings and sensors, providing a cross section time series of surface fluxes and upper ocean variability. Upper air profiles, cloud properties, and surface fluxes are measured during the biannual maintenance cruises on the NOAA ships servicing the 95W and 110 W TAO lines, to sort out interactions between the atmospheric boundary layer and the intertropical convergence zone. Wind profiler data at the Galapagos, located in the heart of the cold tongue, used in combination with other surface and sounding data are used to characterize and understand the dynamic and thermodynamic variability of the lower troposphere over the eastern tropical Pacific. An evaluation of the ability of reanalysis and operational analysis to capture important circulation features in the region is underway.

- Diagnostics of ocean processes: Building on the analysis of mean, seasonal, and interannual variability of zonal currents using CTD/ADCP sections and surface drifter data, the use of historical XBTs shows that the northeastern tropical Pacific is a region of strong off-equatorial upwelling that contributes significantly to both the mean SST patterns and to the general circulation of the Pacific.

  Ocean model experiments demonstrate improvement in simulating the North Equatorial Counter Current using scatterometer winds instead of climatological wind forcing, which poorly captures the ITCZ curl.

- Diagnostics of atmospheric processes: TRMM satellite data analysis shows that the ITCZ in the eastern Pacific has a greater percentage of stratiform precipitation than in the western Pacific, particularly during warm ENSO events. The vertical heating profile associated with the ITCZ stratiform rain has a maximum at greater altitude than to the west. Modeled response to the resulting trans-Pacific gradient in heating demonstrates its importance in realistically simulating ENSO-related atmospheric circulation.

  A newly developed high resolution regional model is used to examine the role of radiative forcing of the eastern Pacific stratocumulus on the cold-tongue ITCZ system. Forcing from stratus generates a shallow local meridional circulation between the ITCZ and the equatorial cold tongue, which could enhance ITCZ precipitation and shift the ITCZ northward.

- Diagnostics of air-sea coupling: An evaluation of local air-sea interaction in the eastern Pacific during the 1997-98 warm event and onset of the 1998 cold event is underway using high-quality SST, air-sea flux, and upper ocean measurements from two WHOI surface flux moorings deployed along 125W from April 1997 through September 1998. Results support the hypothesis that surface winds over the cold tongue are modulated by ocean boundary layer stability.

- Model assessment and improvement: A new formulation of a multi-layer planetary boundary layer in the model produces more realistic cloud incidence than does the single layer boundary layer currently employed. NCAR is introducing a multiple level boundary layer in the next version of its AGCM. Similar testing of the NCEP AGCM is planned for the upcoming year.

  Modeling studies review the importance of incorporating two observed modes of convective precipitation, deep cumulus and stratiform, which account for the effects of downdrafts on the boundary layer. The results suggest improvements in parameterizations of tropical convection in general circulation models.

  An evaluation and ranking of bulk algorithms for ocean surface turbulent fluxes has been completed using direct flux measurements from twelve ship cruises over the tropical and mid-latitude oceans. Results provide guidance for coupled model development.

- Assessing land influences: PACS has investigated the influence of the land on the annual cycle of the eastern Pacific, finding the importance of coastal geometry to maintaining the cross-equatorial asymmetry in the position and occurrence of the ITCZ and cold tongue. A recent study has investigated the influence of orography. Model experiments with and without the Andes demonstrate the importance of the mountains in maintaining the divergence, temperature inversion, and stratocumulus clouds off South America as well as the timing of dissipation of the southern ITCZ in early April.

In FY04, we will support continuation of the projects above, but will not have sufficient funding to initiate new projects that are presently under review. Many of these proposed projects focus on the analysis of EPIC data sets.

1b. Tropical Atlantic Variability

The tropical Atlantic has been shown to provide predictability of climate in the Americas. Shifts in the Atlantic ITCZ associated with tropical sea surface temperature excursions are linked to atmospheric circulation changes that directly impact the intraseasonal to interannual climate of Northeast South America. Evidence also suggests the importance of tropical Atlantic oceanic variations to the frequency and tracks of Atlantic tropical storms and hurricanes. A network of oceanic and surface atmospheric observations of the Atlantic are supported by the Climate Observations program element, while analysis and modelling of tropical Atlantic variability is actively pursued by NOAA's CLIVAR-Atlantic research focus. Leveraging these ocean-focused efforts, PACS examines teleconnections to the Americas from the Atlantic basin. This work is presented in the monsoon discussions in a subsequent section.

2. Understanding and simulating land-atmosphere interaction

Recent research has suggested that land surface processes play important roles in climate predictions. Seasonal predictions conditioned on land memory states have lower variability and therefore higher predictability than unconditioned seasonal predictions. The enhanced predictability results from slowly varying boundary conditions such as soil moisture, snow/ice, and vegetation. Water storage near surface (soil moisture) and on the surface (snow/ice) affect the surface interactions with the overlying atmosphere and the amount of water leaving as runoff in streams or to ground water. The nature and season progression of growing vegetation also represents a land memory and controls surface energy, moisture and momentum exchange. However, the land surface processes and how they affect climate variability and predictions are not sufficiently understood. The representations of those processes in climate models needs need stronger physically based development.

2a. Land Data Assimilation System (LDAS)

LDAS is a joint collaboration between NOAA, NASA, and academic research institutes. Due to the lack of observed soil moisture, LDAS, which runs land surface models in an off-line mode with observed precipitation, can adequately estimate observed land surface hydrologic conditions. The real time LDAS provides the best available land surface initial conditions for climate models. The retrospective LDAS products can be used for climate diagnostic studies and as initial conditions for long-term simulations with climate models. The combination of real time and retrospective LDAS products can be used to produce new drought monitoring products.

In FY03 GAPP continued its support to LDAS in the following activities. A majority of the activities will be continued through FY04.

- Real time LDAS: The real time national LDAS was run operationally to support the NCEP ensemble forecasts from short range to seasonal forecast range, supported by GAPP Core project.

- Retroactive LDAS: Retroactive (1948-present) daily raingauge precipitation products in US and America and Mexico and the surface radiation products from GOES data and algorithm improvements have been produced as inputs for LDAS. The retrospective Land Data Assimilation System data set (1949-present) over U.S. was produced by CPC. GAPP also extended the retroactive LDAS to Mexico to support the North American Monsoon Experiment (NAME). GAPP PIs also worked with the NASA-NOAA Joint Center for Satellite Data Assimilation to better simulate top-of-atmosphere brightness temperatures in LDAS.

- LDAS validation and improvement: GAPP supported a different LDAS approach by using a coupled land-atmosphere model, instead of running land surface model in an off-line mode. This coupled LDAS was found useful especially for mountainous regions. GAPP supported projects to collect observed soil moisture and develop validation strategies to validate the model-driven LDAS products. The GAPP Core project and GAPP PIs will continue to improve the land surface model to improve the LDAS products.

- Global version of LDAS: GAPP supported the global version of the LDAS (GLDAS) by extending the national LDAS driver to execute the Noah LSM on a global domain in NCEP's global seasonal forecast system. The PIs used and tested global LDAS to supply initial land states in the NCEP global forecast system. GAPP PIs also collaborated with NASA partners and transferred the NASA version of the GLDAS to NCEP operations.

2b. Understanding land surface predictability

Several GAPP supported diagnostic/statistical studies have established the knowledge on the linkages on soil moisture with near-surface temperature, soil moisture with precipitation, snow cover in the west with the subsequent season precipitation over U.S.

- Role of land memory: One project found that soil enthalpy anomalies in soil layers resulting from winter snow and snowmelt in the northwestern U.S. can persist several months and affects the following summer precipitation in the southwestern U.S. GAPP also supported a project to develop a new technique to infer snow data from satellite observation. The data could be useful for model validation.

  It was also indicated that there is a close interaction between water and carbon cycles through the soil moisture impact on both evaporation and carbon assimilation.

  The PIs coupled AGCMs with NOAH land-surface scheme to test the hypothesis that local modifications of the large-scale circulation through regional-scale atmosphere-land surface interactions are crucial in shaping land-surface conditions in the western and southwestern U.S. during winter and spring.

- Spatial and temporal extent of land memory signals: One GAPP supported research indicated that the relation between land surface characteristics (such as stomatal conductance, soil-surface wetness, leaf area index, surface roughness, and albedo) and the surface heat and momentum fluxes is strongly nonlinear. Furthermore, land surface heterogeneity can induce atmospheric mesoscale circulations, which have a strong impact on the structure of the atmospheric planetary boundary layer, clouds, and precipitation. These findings imply that appropriate land surface schemes for large-scale atmospheric models (e.g., general circulation models) need to provide higher-order statistical moments and characteristic length scales of discontinuity (CLSD) of the land-surface characteristics.

- Water and Energy Simulation and Prediction (WESP)*:* WESP studies are designed to understand what components of the global water and energy cycle can be measured, simulated, and predicted at regional and global scales. In FY03, GAPP contributed to WESP by providing in-situ, remote sensing, and global and regional land and coupled assimilation products for GAPP area and global domain; The PIs have developed a preliminary water and energy budget synthesis (WEBS) for Mississippi River Basin for the period of 1996-1999. The results suggested that we still can't close the budget with the current observations and global/regional models;

2c. Representing land surface processes in uncoupled and coupled models

In FY03, GAPP supported land surface modeling studies to improve parameterizations of land surface processes, to demonstrate the improvement in climate simulations, and to incorporate improvements into operational climate forecast systems.

- Improving parameterizations of land surface processes: The Core project tested groundwater treatment in the baseflow-runoff component of Noah model. The cause of the overly rapid drop-off in the baseflow in Noah model has been found to be the lack of groundwater storage in the model.

  GAPP is supporting a MOPEX (Model Parameter Estimation Experiment) project to develop "a priori" parameter estimation for land surface and hydrologic models. They will test whether the model parameters developed for one region can be transferable to other regions.

  The PIs Formulated and demonstrated improved treatment of the subsurface heat flux under relatively shallow patchy snow cover. Reduced the early bias in Noah seasonal snowmelt by improving the albedo over snowpack

  In order to account for vegetation feedback at the seasonal time scale, GAPP supported a project to incorporate a dynamic vegetation scheme into the land surface model. The modified land surface model reproduces the seasonality of the observations with reasonable accuracy. However, there are some discrepancies between the predicted and observed at local-regional scales, especially in drought cases.

- Demonstrating improvement in climate simulations: The results from a GAPP supported project found that a significant warm bias both in Eurasia and North America from the default NCAR Community Climate Model (CAM2/CLM2) was largely reduced by using an improved snow scheme.

- Improving NCEP operational climate forecast system: The GAPP Core Project has incorporated the improved Noah land surface model into the NCEP global prediction model. Currently this experimental global prediction model is running in parallel to the operational version using the old OSU land surface model. The Core project is assessing the new Noah model by making two global climate model simulations with these two land models and comparing the results to the in situ observations from CEOP (Coordinated Enhanced Observation Period).

2d. Regional climate modeling

A growing body of literature is increasingly established that high resolution regional climate models driven by time-dependent atmospheric lateral boundary conditions from GCMs can be used to successfully downscale climate simulations generated from relatively coarse resolution global models. The reasons for the success of imbedded regional climate models are their ability to better resolve the land surface characteristics, orographic influences, diurnal cycle, SST gradients in nearby coast ocean areas and convective complexes.

- Assessing the ability of regional climate models: The Core project executed long-term ensemble simulations with both analyzed and predicted lateral boundary. The simulations are examined to compare to what extent the forecasts deteriorated from the use of predicted versus analyzed lateral boundaries and to examine the ability of the NCEP regional climate model to capture interannual variability.

- Identify the key issues in regional climate modeling: One GAPP funded project found that regional climate model simulations depend on location of the domain and the domain size of the region. PIs also found the RSM-simulated precipitation is sensitive to choice of physics/surface parameterizations (e.g, convective parameterization). Results suggested to use ensemble of different physics packages other than the use of a collection of models.

- Improving operational climate forecast system: The Core project developed NCEP's first Regional Climate Model. In FY03, as a major step toward true operation mode, the Core project constructed and tested the RCM configuration that utilizing actual predictions of lateral boundary conditions from the NCEP global seasonal forecast system.

In FY04, GAPP will continue the above land process and variability studies. GAPP will support several new projects to validate, downscale, and/or analyze Regional Reanalysis and retroactive LDAS data to quantify the strength of the land memory processes, the spatial/temporal variation of land-memory, and their roles in climate variability and prediction. GAPP will also support a new project to examine how the surface and groundwater exchange modulate the climate signal and provide memory for hydrologic prediction.

3. Coupled Ocean-Atmosphere-Land System

3a. Regional Reanalysis

Under GAPP support in FY03, NCEP finished the first 23 years (1979-2002) of 25 year Regional Reanalysis. Using the most recent version of the Noah land model and a new precipitation assimilation scheme developed through the GAPP initiative, the Regional Reanalysis project has produced the reanalysis products at 32 km over the North America. Preliminary studies indicate that the Regional Reanalysis, on its domain, has produced precipitation, soil moisture and other related fields that are far superior to the NCEP/NCAR Global Reanalysis. Just as the Global Reanalysis products were widely used, it is anticipated that these Regional Reanalysis products will be used extensively and will lead to many new research findings about intraseasonal to interannual variability over North America.

During FY04, the project will finish the rest of 25 years of the analysis and make the data accessible by the broad science community. The project will also establish the real time system for transition to Climate Prediction Center to produce real time Regional Reanalysis products.

3b. North American Monsoon Experiment (NAME)

Since 2001, PACS and GAPP have jointly supported the Warm Season Precipitation Initiative to determine the sources and limits of predictability of warm season precipitation over North America. More recently, the program has been reoriented to address the science objectives of the North American Monsoon Experiment (NAME).

Science planning for NAME calls for simulations of the North American Monsoon System that, at minimum, adequately represent the location, spatial structure, and diurnal cycle of precipitation. Studies to date suggest that current models do not satisfy this requirement. Coarse-resolution GCMs tend to underestimate precipitation while high-resolution regional models tend to overestimate precipitation.

In FY03, PACS and GAPP together supported 25 observation, data set development, analysis and modeling projects under this initiative.

- Enhanced observations: In order to better resolve moisture fluxes and rainfall variability in the core region of the North American monsoon, PACS augmented the upper air wind sounding network along the Mexican coasts, expanded the precipitation gauge network in the data sparse terrain of the Sierra Madres, and upgraded Mexican operational Doppler radars to capture research quality precipitation and circulation data.

- Monsoon monitoring: The program established real-time Pan-American monsoon monitoring and analysis system at NOAA's Climate Prediction Center in support of community-wide American monsoon research and the development of climate services. Real-time gauge and satellite precipitation data sets, assimilation products, and historical reanalysis for the US, Canada, Mexico, and Brazil are available online.

- Model capability assessment: A coordinated effort to document and assess the diurnal cycle simulated in AGCMs at the four major US modeling centers (GFDL, NCEP, GSFC, and NCAR) has been launched. Modeling experiments are underway to identify and quantify the physical processes driving the diurnal cycle, to evaluate the impact of model resolution, and to assess the impact of changes in boundary layer, land surface and cloud parameterization schemes. Feedback will be provided to the model development groups at the four centers, providing guidance for improving physical parameterizations.

  An intercomparison of global and regional model simulations of the 1990 North American monsoon season (characterized by heavier than normal rainfall) has been completed. While demonstrating that all six of the participating models do simulate a summer precipitation maximum, the analysis exposes a range of uncertainties in the simulated diurnal cycle of convection and rainfall, and huge differences in surface temperature and heat fluxes. Further simulations and comparisons for average and weak monsoon years are planned.

- Monsoon diagnostics: A moisture budget analysis over the southwestern US uncovers upper-level moisture divergence from the region, refuting an earlier-held hypothesis that large-scale upper-air moisture advection from remote source regions fuels the summer monsoon. Southwest summer rainfall is balanced by vertical diffusion of moisture supplied by local evaporation, largely from the Gulf of California.

- Drought diagnostics: A study of the major 2002 drought in Texas, New Mexico, and Mexico determined the cause was not a lack of moisture availability, but instead persistent large-scale subsidence over the region. Analysis of historical drought over the Central US reveals systematic links with the PDO, but no strong relationship to ENSO.

- Role of ocean forcing: An observational study of the interannual variability of the North American monsoon system finds time-evolving teleconnection relationships associated with ENSO and PDO. Model experiments testing the response of the monsoon to Pacific SSTs corresponding to positive and negative phases of ENSO and PDO.

- Role of land surface processes: Intensive research is pursuing the response of the summer monsoon system to land surface forcing. Results suggest that summer soil moisture anomalies may affect the local hydrologic cycle throughout the summer via local water recycling. Several empirical and modeling studies have found a strong negative relationship between summer monsoon precipitation and the preceding winter/spring snowpack. Vegetation has also been found to represent a significant source of memory for the monsoon climate. A regional coupled land-atmosphere modeling study is investigating if and how introducing a description of interactive vegetation growth influences the modeled spatial and temporal variability of the North American Monsoon.

- Monsoon remote influences: Earlier empirical work uncovered an out-of-phase relationship between precipitation in the monsoon region and that over the Great Plains. Such a connection offers the potential for prediction over a greater expanse of North America, beyond the monsoon's core. A mechanistic understanding of the empirical relationships is advancing. A recent analysis indicates a simultaneously occurring out-of-phase relationship between the Great Plains low level jet and the Gulf of California low level jet (GCLLJ). Another suggests that the development of a mid-to-upper level anticyclone during the monsoon may block moisture transport from the west to the Great Plains.

In 2004, a major focus of PACS and GAPP will be in the North American Monsoon Experiment (NAME) field campaign planned for June-August. An international and interagency coordinated research program, NAME 2004 aims at determining the sources and limits of predictability of the core monsoon over North America. The plan of the field campaign is motivated by previous and ongoing diagnostic and modeling studies, which reveal important processes contributing to the variability of monsoonal circulation, convection and precipitation. NOAA PACS and GAPP will be supporting 11 field projects, significantly enhancing the space and time resolution of ocean, atmosphere, and land observations in the core monsoon region of Northwest Mexico and the Southwest US. Field observations are planned to (1) resolve the wind, temperature, and moisture fields at sufficient spatial and temporal resolutions around the Gulf of California, in order to define the mean structure of the troposphere and its variability on monthly to synoptic to diurnal time scales, and (2) describe and understand the convective organization, dynamics, microphysics and life cycle of precipitation systems in the core region of the monsoon, including their diurnal variability. The goal of this effort is to better understand regimes associated with intra-seasonal variability of convection during July-August over northwestern Mexico and its linkages to precipitation in the southwestern U.S.

A limited number of new analysis and modeling projects are to be initiated in FY 2004. They will examine the influences of surges, jets, easterly waves, ocean and land surface fluxes, and orography on monsoon initiation and variability. We'll also support projects to analyze the hydrologic cycle component of the monsoon system to enable hydrologic interpretation of improved summer season climate forecasts.

3c. Monsoon Experiment over South America (MESA)

The South American monsoon focus of PACS, and now CPPA, includes studies to describe, understand, and model key components of the seasonally varying climate over South America, principally the response of the continental monsoon system to changes in sea surface temperatures and atmospheric circulation over the Pacific and Atlantic basins and to variations in land surface conditions, including soil moisture and vegetation.

A key feature of monsoonal South America, the low level jet located over the altiplano region to the east of the Andes, channels the flow of moist air from the Amazon basin to the breadbasket region of southeastern South America where it feeds summertime storms and exerts controlling influences on droughts and floods in the La Plata basin. Operational observation and data assimilation systems do not resolve the spatial and time variability of the jet. Uncertainties of 50% are found in monthly averaged moisture flux out of the Amazon and into the La Plata basin. Improved monitoring and modeling of the low level jet is essential to advancing climate prediction over much of eastern South America,

- Enhanced monitoring: The South American Low Level Jet Experiment (SALLJEX), undertaken by scientists in Argentina, Brazil, Bolivia, Paraguay, and the US, was launched November, 2002, for eight weeks to intensively measure the atmosphere over central South America, one of the largest over-land atmospheric data voids on the planet. The existing balloon sounding network over South America was augmented with an additional fifteen sites in northern Chile, northwestern Argentina, and the altiplano of Bolivia and Peru. The surface rain gauge network was also enhanced in the region with an additional 1200 sites. The ground-based observations were augmented by wind and moisture measurements made along and across the core of the jet by a NOAA P-3 aircraft. Much of the effort since the field campaign has been devoted to developing quality controlled and integrated data sets from the raw observations.

- Monsoon diagnostics: Analyses to characterize South American climate variability on intraseasonal to interannual timescales continue. Specific efforts aim to document and determine the causes of the seasonal migration of the monsoon rains, and the climatology of extreme events.

- Role of ocean forcing. A new nested modeling system to simulate regional-scale subseasonal to interannual variability of precipitation and atmospheric circulation over South America in response to observed SSTs is being developed and tested at the IRI. A preliminary 20-year run of the global model alone, without nesting, already shows good skill.

  While previous work has examined the tropical Pacific influence on seasonal climate, a new study has recently completed an unprecedented documentation of the empirical relationships of seasonal precipitation anomalies to simultaneous and precursor Atlantic SST signals. In addition to finding tropical Atlantic linkages, the subtropical South Atlantic is found to strongly modulate precipitation south of 10S during all seasons, with warm SST anomalies linked to enhanced rainfall.

- Role of land forcing: Model simulations testing the influence of land surface moisture on the strength of monsoon suggest a negative feedback loop linking soil moisture, stratus extent, shortwave radiation at the surface, evaporation, and convective precipitation. A new formulation of radiation parameterization is being developed to incorporate the impact of mesoscale orographic variations on cloud-topped boundary layers.

- Remote monsoon influences: South American monsoon convection is found to influence climate variability in remote regions, including North America and the East Pacific. The increase of warm-season rainfall over the Amazon is found to amplify the northern hemisphere winter anomalous atmospheric circulation patterns associated with the NAO, which in turn influence winter weather patterns over eastern North America. An intermediate coupled model is employed to study how air-sea interaction and continental convective heating associated with the monsoon systems affects the annual cycle and mean climate of the tropical Pacific.

  The South America monsoon is found to affect the eastern Pacific southeast trades and SST annual cycle. In contrast, the Columbian, Central and North American monsoons have little impact on the annual cycle of SST in the cold tongue. Other model experiments examine possible feedbacks controlling the interaction between the continental monsoon over South America and the subtropical anticyclone system in the Eastern Pacific.

In FY 2004, the current set of analysis and modeling projects will continue to explore the variability and predictability of South American climate and its remote influences. Quality- controlled SALLJEX data sets will be made available to the research community via a web-based directory. The data will be used to evaluate the veracity of numerical representation of the low level jet in atmospheric models used at NCEP, Brazil's CPTEC, and the IRI. Modeling experiments are planned to determine the degree of detail required to produce realistic precipitation patterns, including the diurnal cycle. Further modeling research will assess and improve initial state representation and parameterizations to advance intraseasonal to interannual prediction over South America. Due to budget constraints, new projects selected from the pool of FY 2004 proposals will be delayed until FY 2005.

3d. Western Mountain Climate

In regions with marked orography, such as, the U.S. West, climate conditions can be significantly modulated by orographic features that vary in different spatial scales. Orography has a well-recognized and persistence influence on precipitation and hydrologic flows and, depending on the time of year, can determine whether precipitation falls in liquid or solid form. Our ability to predict regional scale seasonal climate anomalies therefore depends strongly our understanding of the dynamic and thermodynamic effects of orography and its interactions with anomalies of large scale circulations.

This is a relative new research area to CPPA, but an excellent opportunity for CCPA to get experts in land surfaces, hydrologists, regional and large scale modelers to study the relationship between orography, climate and hydrological variables in mountainous area.

In FY 2003, GAPP funded two projects to study the orographic effects.

- A set of simulations of regional climate models with different horizontal resolutions has been made to study the orographic effects on climate. Results show that high resolution is important for climate models to resolve the impact of orography. During winter, higher resolution generally improves the spatial distribution of precipitation to yield higher spatial correlation between simulations and observations. During summer, higher resolution improves not only spatial distribution but also regional mean precipitation.

- A newly funded project is examining cross mountain flow, along-mountain wind channelling and their effects on rainfall distribution. Model results will be validated with Regional reanalysis data and observations.

In FY 2004 those projects will be continued. The mountain studies will be a focused research area for FY 2005.

4. Applications in water resource management

While the importance of improved climate prediction in water resource management is well recognized, it remains a challenge to translate such improved climate predictions into usable information for water management. One of the GAPP objectives is to interpret and facilitate the transfer of the results of improved seasonal climate prediction for the optimal management of water resources. GAPP collaborates with many agencies (e.g., NASA, B. of Reclamation), NOAA line offices (e.g., Office of Hydrology, River Forecast Centers), and university scientists as partners or clients.

4a. Improvement of hydroclimatic forecasting

- Seasonal Hydrologic Forecast System: In FY 2003, a GAPP project established an experimental seasonal hydrology forecast system in the West and East basins based on CPC's hindcast runs and a set of forecast runs with the Global Spectrum Model (GSM). The PIs plan to extend the system to the entire U.S. The NWS office of hydrology component of the GAPP Core Project developed plans to implement and test an experimental national hydrologic prediction system that would produce ensemble runoff forecasts for lead times of one month to one year using a monthly hydrologic model, CPC monthly and seasonal probabilistic forecasts and AHPS ensemble precipitation procedures applied to the CPC forecasts.

- Hydrologic predictability studies: A GAPP supported project has found that for the western basin the land surface state has a stronger predictive capability than climate indicators through leads of two seasons. Climate indicators are more important for eastern areas at lead times of one season or greater.

- Pre-processing climate forecasts: A statistical procedure has been developed to re-scale or downscale climate forecasts for streamflow forecasts in individual river basin. A multi-objective, step-wise calibration procedure has been developed to improve hydrologic model simulations of streamflow.

- Ensemble hydrologic forecasts: The GAPP PIs have collaborated with AHPS to improve hydrologic application of ensemble precipitation forecasts including developing ensemble precipitation verifications procedure, developing ensemble downscaling procedures, and post-processing the hydrologic forecasts to account for effects of hydrologic biases.

4b. Development of decision support tools

- Help water managers understand and use climate predictions: An on-line interactive demonstration/evaluation system was established to allow water resource managers to explore interpret and evaluate CPC forecasts. Several briefings were given to help users to use this system.

- Forecast verification: The Core project PIs collaborated with GAPP PIs to verify AHPS forecasts for the Des Moines river basin. This required further development of existing NWS river forecast system retrospective ensemble streamflow prediction capability. An operational verification data set for the Des Moines River basin was used to investigate bias-correction methods for ensemble streamflow forecasts for use in operational decision-making. This case study provides a template for using AHPS products in water resources decision-making. The GAPP Core project also developed a generalized AHPS ensemble verification method to provide a framework for infusing new ensemble verification techniques into NWS operations.

- Assess and demonstrate the predictive capability: The PIs are developing a systematic procedure for assessing the value of seasonal climate forecasts and applying it to a multi-reservoir system of the Lower Colorado River Authority. This procedure is to assure validity of probabilistic forecast information to be used by the water resources decision-makers.

In FY 2004, GAPP will continue to support the above activities. The Office of Hydrology component of the Core project will continue to play an important role in water resource applications.

Scientific Planning

Science and implementation planning for CPPA will be guided through consultation in the US with the CLIVAR Pan American Panel and the GAPP Science Advisory Group. International coordination is provided through International CLIVAR's Variability of the American Monsoons (VAMOS) Program and the International GEWEX Science Steering Group. Support is provided for operations of the program coordinating offices, the meetings of these groups, and workshops to coordinate community research.

FY 2004 Budget Plan

Budget information covering fiscal years 2003 to 2005 for the combined PACS and GAPP programs is provided in the following table. In FY 2003, the programs operated separately with the significant exception of their joint initiative on North American warm season precipitation. For FY 2004, separate solicitations for proposals were issued as discussions were initiated for combining the programs into a single CPPA. Significant joint budget planning between the programs, including redirection of resources, has been required to meet the resource requirements for the NAME 2004 field year.

CPPA Budget $ in Thousands

Research Topic	FY03	FY04
Ocean-Atmosphere Interactions	1,960	1,770
Land-Atmosphere Interactions	1,620	1,400
Coupled Ocean-Land-Atmosphere System		
Regional Reanalysis	640	250
North American Monsoon	2,320	3,000
South American Monsoon	600	850
Western Mountain Climate	180	230
Water Resource Applications	550	400
NCEP Core Project	950	950
Science Planning	330	300
TOTAL CPPA	9,150	9,150

Assuming level funding in FY 2004 at the FY 2003 level for PACS and GAPP, the budget for CPPA would be \$9.15M. An alternate scenario, which reduces the Climate and Global Change program budget by 5%, decreases the CPPA budget by \$450K to \$8.7M. At the reduced level, we would delay awards for newly reviewed and selected PACS/GAPP North American modeling and analysis projects until the beginning of FY 2005.

For FY 2005 and beyond, a program plan is under development by the program managers in coordination with the CLIVAR-Pan America and GAPP science advisory committees to organize and launch the CPPA program. This plan will guide the solicitation of new project proposals for FY 2005.